GPM

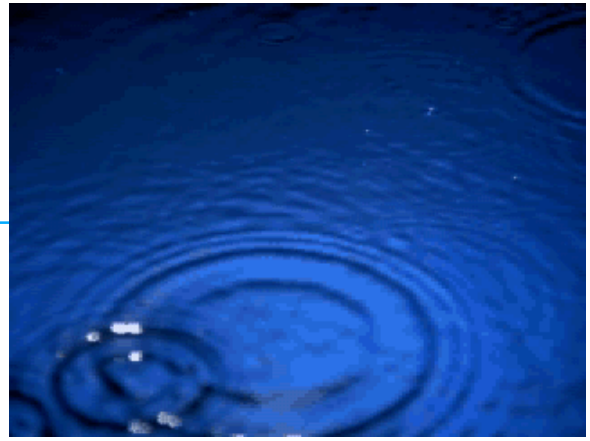
GLOBAL PRECIPITATION MEASUREMENT

Global Precipitation Measurement (GPM)

Ground Validation System

GPM System Definition Review

December 6-8, 2005

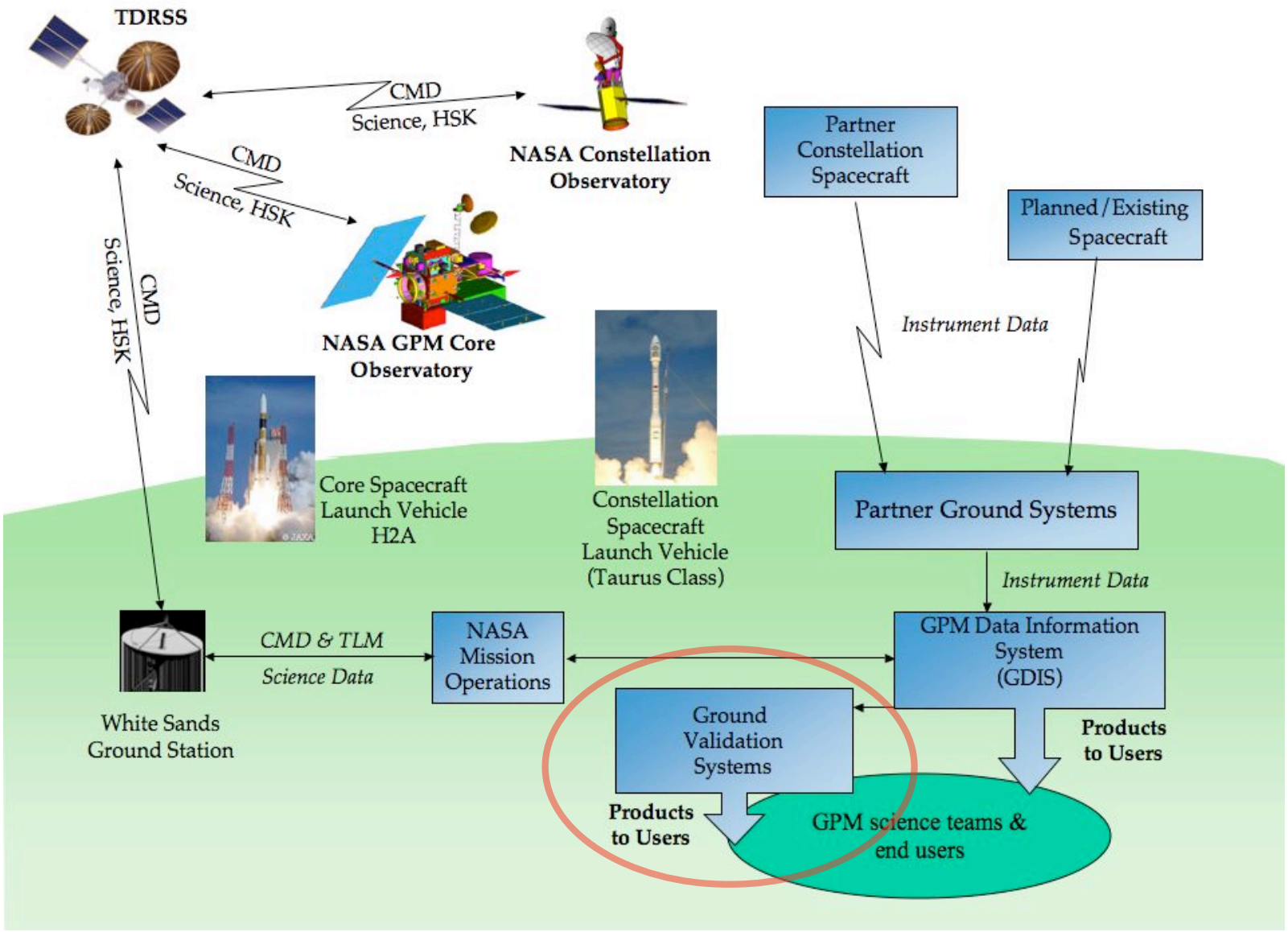


Mathew Schwaller
GPM Formulation Project
Ground Validation Manager
mathew.r.schwaller@nasa.gov
Goddard Space Flight Center

Presentation Outline

1. **Introduction**
   - *System architecture*
   - *July 2002 SRR concerns*
   - *GV requirements definition process*
2. **GVS Level-2 Requirements**
3. **GVS Functional Description**
   - *GVS context diagram*
   - *Major GVS functions*
   - *Nominal operational data flow*
4. **GVS Implementation Concept**
   - *Statistical & physical validation*
   - *Instrumentation & site locations*
5. **Wrap-up**
   - *Schedule, risks, staffing*

GPM System Architecture



Review Team Comments from the July 2002 SRR

SRR risk item related to GPM GV:

The project recognizes that the Ground Validation System (GVS) is still in the formulation stage and better definitions are required before the commencement of preliminary design. ***The GVS requirements and implementation concepts should be more effectively defined*** *to convey the notion that although the GVS is not launch critical, it is extremely critical for science data quality and ultimately mission critical*

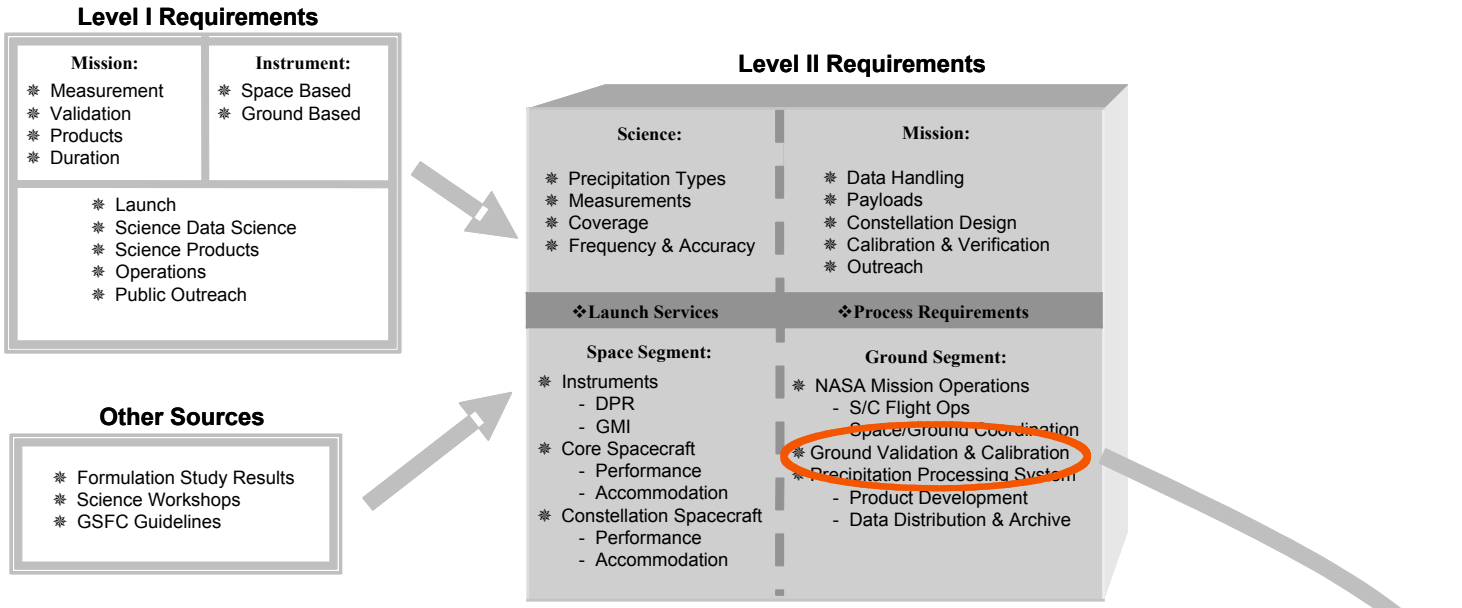
- *Considerable effort has been made since 2002 in the requirements definition process for GPM GV*
- *The implementation concepts and requirements defined here represent a major revision to those presented in 2002*

GPM Ground Validation Requirements Definition Process

- ***GVS Level-2 Requirements Peer Review March 2004***
  - *41 RFAs received; responses completed September 2004*
- ***Framework Concept for GPM GV developed and circulated July 2004***
  - *First draft circulated to PMM Science Team and others*
  - *Defined major GVS concepts*
  - *Version-9 circulated in May 2005*
  - *Numerous comments received; led to significant revision of GVS requirements*
- ***GV L2 Delta L2 Requirements Peer Review December 2004***
  - *37 RFAs received; responses completed January 2005*
  - *Actions taken in response to RFAs:*
    - *6 new requirements*
    - *3 existing requirements modified*
    - *9 new GVS-level risk items added (2 subsequently closed)*
    - *1 new GPM-mission level risk item added*
  - ***Written comments from Jeff Privette, Chair of the GPM GVS Peer Review panel:***
    - ***"The GVS design maturity is significantly more developed relative to its state in the first Peer Review. The presentations were solid and informative, and our questions were typically answered to our satisfaction. It is clear that much thought and work has gone into this design. The Review Team congratulates the GVS team on a job well done"***

GVS Requirements

GVS Requirements



- GVS Level 3 Requirements
  - Measurement and product generation
  - Archive and distribution
  - Precipitation and hydrology analysis
  - Metrics
  - Interfaces
- GVS Level 3 Operations Concept

GVS Level 1 Requirements

3.1.1.4 *The GPM Mission shall utilize ground-based instrumentation within GPM satellite ground tracks to ascertain in-situ precipitation characteristics for satellite algorithm refinements and to provide related environmental parameters*

3.1.3.4 *The GPM Project shall provide a Ground Validation System (GVS) to conduct independent characterization and assessment of GPM space-borne measurements and products at targeted continental and oceanic locations covering different precipitation regimes within the ground track of the NASA GPM core satellite*

GVS Level 2 Driving Science Requirements

7.4.1.1 Direct assessment of satellite precipitation estimates

The GVS shall facilitate statistical comparison of GPM satellite precipitation products with estimates provided by the U.S. national radar and rain gauge networks for identifying and resolving significant discrepancies between space-borne and ground-based measurements

7.4.1.2 Precipitation physics measurements for satellite observation simulation

The GVS shall provide measurements of precipitation physics and ancillary observations for simulations of satellite measurements to improve the understanding and modeling of precipitation processes including error characterizations for satellite retrieval algorithm improvement

7.4.1.3 Assessment of satellite precipitation estimates in hydrological applications

The GVS shall have the capability to assess satellite precipitation products using hydrological basins as an integrated measure of data quality in hydro logical modeling and prediction

GVS Functional Requirements

7.4.2.1 Measurement

The GVS shall make atmospheric measurements using ground -based instruments at a minimum of two sites within view of the NASA GPM core satellite

7.4.2.1 Product generation

The GVS shall generate products as necessary to conduct cross -comparison of ground-based measurements and GPM core and constellation satellite obse rvations and product retrievals

7.4.2.1 Archive

The GVS shall archive all of the data, products, reports, documentation, and computer code necessary for its operations

7.4.2.1 Archive search and order

The GVS shall permit search and order data, products, reports, documentation, and computer code from its archive

7.4.2.1 Distribution

The GVS shall distribute its archive holdings of data, products, reports, documentation, and computer code to users on request

7.4.2.1 Metrics

The GVS shall generate, archive, and distribute metrics as needed for analysis of system performance and for system management

GVS Operations Requirements

7.4.3.1 Ready for Operations

The GVS shall be ready for operations at least 6 months prior to the projected launch of the GPM core satellite

7.4.3.2 Operations Lifetime

The GVS shall operate for the minimum required lifetime of the GPM Core and Constellation Satellites

7.4.3.3 Nominal Operations

The GVS shall nominally operate on a 5-day per week, 8-hour day work schedule, with unattended operations after hours and during holidays

7.4.3.4 Transition to Long-Term Archive

The GVS shall, at the end of its lifecycle, make all current versions of materials in its archive available for long-term archive by an organization external to the GVS

GVS Performance Requirements

7.4.4.1 New and Updated Instruments and Methods

The GVS shall permit the introduction of new or updated instruments and methods throughout its period of performance

7.4.4.2 Product Generation Timeliness

The GVS shall generate products within 24 hours of r eceipt of the required input data during nominal operations

7.4.4.3 Product Distribution Timeliness

The GVS shall distribute products within 24 hours of generation during nominal operations

GVS Interface Requirements

7.4.5.1 Interface to the PPS

The GVS shall receive GPM core spacecraft planning and scheduling data from the Precipitation Processing System (PPS)

7.4.5.2 Interface to the PMM Science Team

The GVS shall receive product generation and validation algorithm s from the Precipitation Measuring Missions (PMM) Science Team

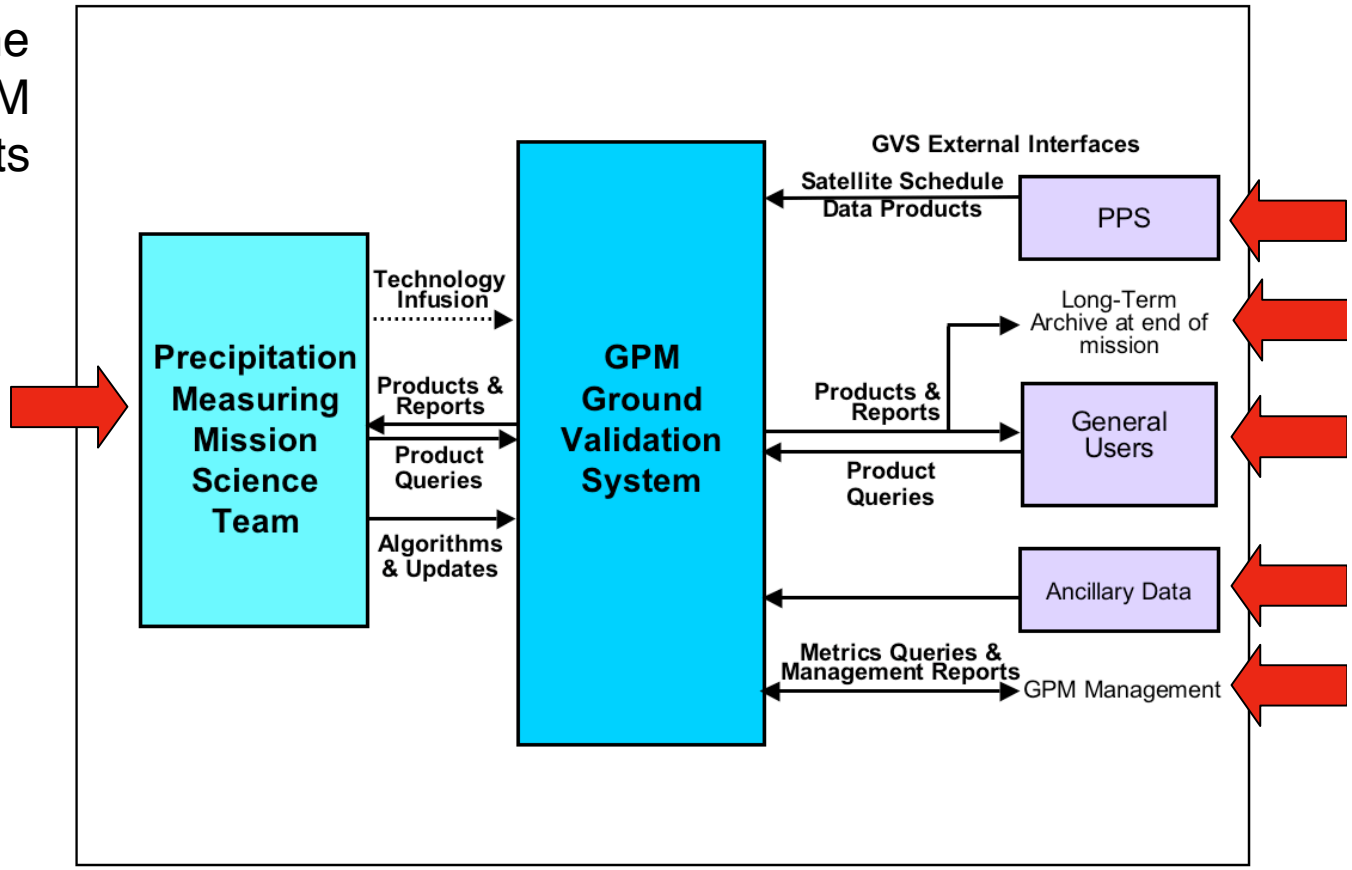
7.4.5.2 Ancillary Data

The GVS shall ingest ancillary data for GVS product generation

GVS Functional Description

GPM-GVS Context Diagram

GPM-GVS in the context of other GPM and external elements



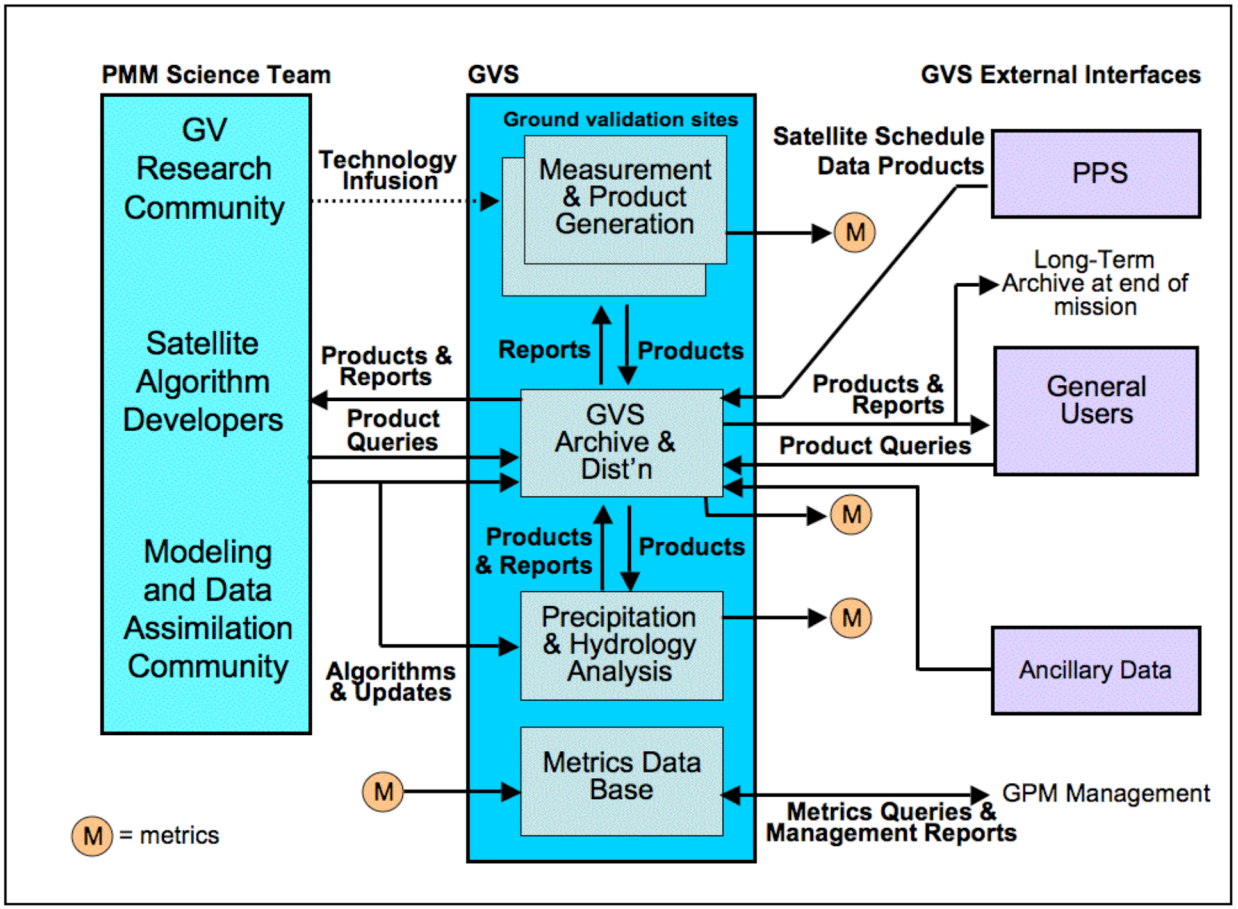
Roles of GPM-GVS External Elements

- ***PMM Science Team***
  - *Identifies requirements for GV instrumentation, analysis techniques and products*
  - *Assist in the selection and initial operation of GV instrumentation*
  - *2-way interaction with the GPM-GVS archive & distribution capabilities to search & order GVS data products*
  - *May interact with the user services capabilities of the GPM GVS*
  - *Over time, the PMM Science Team makes recommendation on infusion of new instrument technologies and techniques, new analytic techniques and products*
- ***Precipitation Processing System***
  - *Provides GPM overflight schedules (and updates as needed) to the GVS*
  - *Provides GPM data product subsets geolocated over GPM-GVS ground sites*
- ***General Users***
  - *World-wide community can search & order GPM-GVS products*
  - *GPM-GVS user services (human contact) available to PMM Science Team members but not to the general public*
- ***Ancillary Data Sources***
  - *GPM-GVS SSM will require data products (e.g., satellite data, operational weather data)*
  - *Specific requirements for these data will be coordinated with the PMM Science Team and identified in lower-level documentation*
- ***GPM Management***
  - *The GPM-GVS will generate routine performance metrics during operations, and will provide routine reports to GPM management*
  - *GPM management may also query the GVS metrics database for unique reports as needed*
- ***Long-Term Archive***
  - *At the end of its life-cycle the GPM-GVS will provide a copy of all current versions of data, products, reports and product generation software for delivery to a non-GPM long term archive*

Major GPM-GVS Functions

Four major functions:

- **Measurement & Product Generation**
  - *Handles most instrument observation functions*
- **Archive and Distribution**
  - *Stores products and manages user interface to the GVS*
- **Precipitation & Hydrology Analysis**
  - *Handles most analytic functions, including the "National Map" see chart #27*
- **Metrics Database**
  - *Collects performance metrics from the other functional elements*
  - *Permits management insight into distributed elements of the GVS*



*NOTE! This **functional breakdown** is only used to organize the GPM-GVS requirements. **It should not be interpreted as a physical architecture!** Physical attributes and implementation specifications of the GPM-GVS will be documented in the PDR.*

Measurement & Product Generation Function Summary

- ***GPM GV instrumentation is allocated to at least 2 MPG sites***
- ***Each MPG site may have different instrumentation, but both share common polices and practices, including***
  - *Ground instrument calibration/validation, including traceability and tracking*
  - *Staffed nominally on a 8-by-5 schedule, with unattended operations after hours*
  - *Goal of observing and recording all precipitation events within the ground site*
- ***PMM Science Team assists in definition and deployment of MPG instrumentation and methods***
  - *PMM Science Team is source for infusion of new instrumentation and techniques throughout the mission*
- ***MPG generates data products as required by the GVS Precipitation & Hydrology Analysis (PHA) function***
- ***MPG receives PPS data products***
  - *Spacecraft overpass schedules (and updates)*
  - *Standard products subset to the geographic location of the GVS ground sites*
- ***MPG generates process and performance metrics, and delivers them to the GVS Metrics Database (MD) function***
  - *Metrics could include, for example: reports on instrument outage and malfunction; instrument noise and drift; error characteristics of M&PG measurements and products; delivery performance and quality of products received from the PPS, …*

GVS Precip & Hydrology Analysis Function Summary

- ***PHA executes the basic evaluation and diagnostic activities of the GVS:***
  - *Integrates satellite and ground observations (National Map, see chart #27)*
  - *Forward modeling, and other assessments as required*
  - *Reporting on cross-comparison of direct observation with calculated parameters*
- ***PHA generates process and performance metrics, and delivers them to the GVS Metrics Database (MD) function***
  - *Metrics report on full scope of activities listed above*
- ***PHA receives data needed to conduct mapping and analysis from the GVS Archive and Dist'n (A&D) function***
  - *Products from A&D could include those from the PPS, GVS-MPG, and from ancillary data sources*

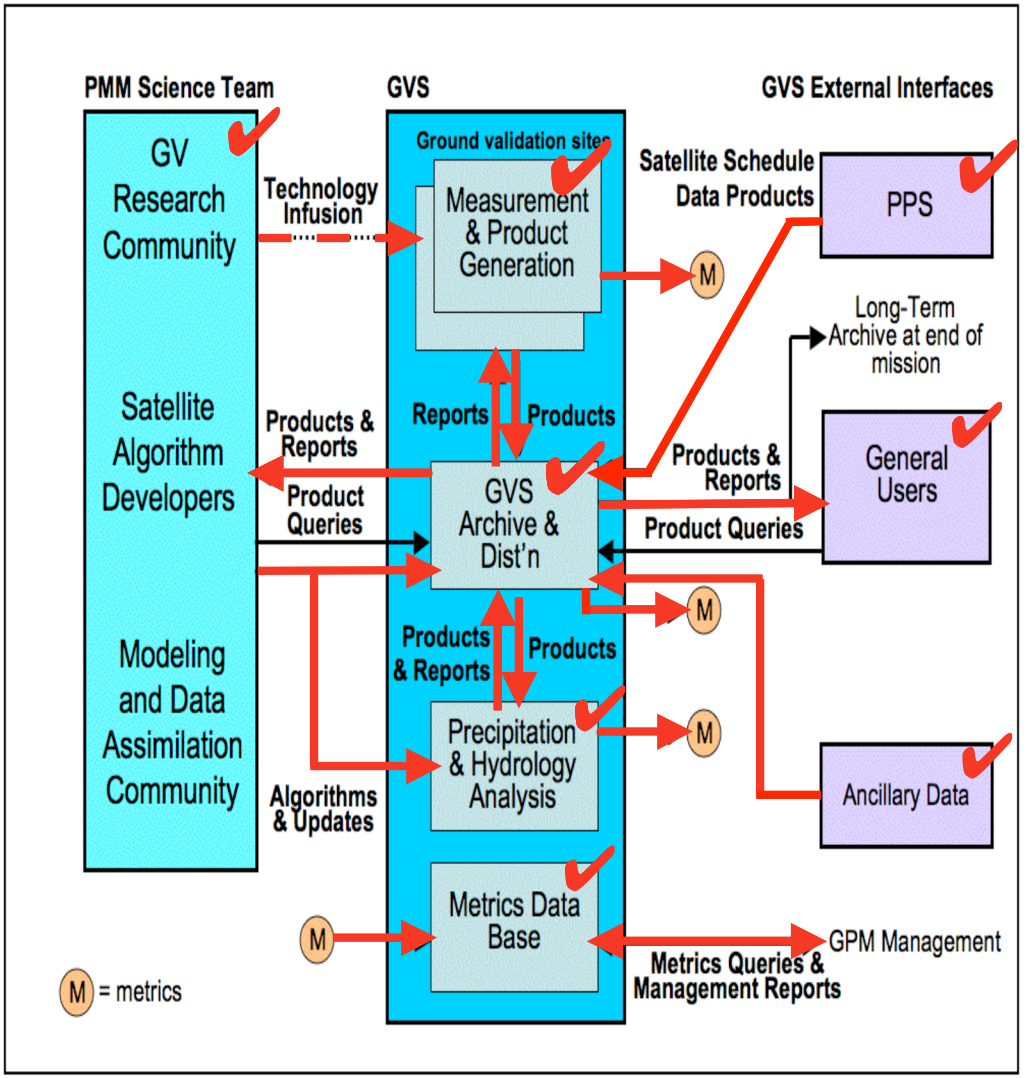
GVS Archive & Distribution Function

- ***A&D provides secure and reliable storage of and access to all GVS:***
  - *Data, products, documentation & reports generated by GVS-MBA, GVS-MPG*
  - *Data products received from PPS (via MPG) and from ancillary data sources*
  - *Site for archive of computer code used in product generation by MBA and MPG*
- ***A&D provides Internet-based search, order and distribution capabilities for access to its holdings***
  - *Also allows for "standing orders" of routine products*
- ***A&D provides limited customer service for PMM Science Team members***
  - *Allows for email exchange on 8x5 basis to address questions about products and services; this is not available to the general public*
- ***A&D generates performance metrics and delivers them to the GVS Metrics Database***
  - *Performance metrics could include, for example: data quality checks, volume of data & granules ingested/distributed, number of searches and orders, …*

GVS Metrics Database Function

- ***MD receives performance and process metrics from the MPG, MBA, and A&D functions***
- ***MD provides safe and reliable storage for all GVS performance and process metrics received***
- ***MD provides GPM management with routine "standing orders" of database reports***
  - *Reports can be triggered by dates or events*
- ***MD permits GPM management to search the metrics database and to generate 1-time user-defined reports***

Nominal Operational Data Flow (Picture)



Nominal Operational Data Flow

1. *The PPS determines and periodically distributes scheduling information on GPM constellation and core spacecraft overflights of GPM GVS ground site locations. The GVS MPG and the spacecraft measure the same precipitation events at the same time.*
2. *The GVS MPG, the GPM core spacecraft, and the GPM constellation spacecraft measure precipitation events on an ongoing basis; the spacecraft measure events across the globe, while the GVS measures the events at local sites.*
3. *The PPS generates L1 and L2 data products for core and constellation spacecraft, extracts subsets of the data corresponding to GVS ground site locations, and delivers the subsets to the GVS A&D.*
4. *The MPG sites generate data products that characterize the atmospheric state during a precipitation event. These data products are delivered to the GVS A&D.*
5. *The A&D distributes MPG data products to Precipitation Measuring Mission Science Team members and to the general user community according to previously established standing orders or in response to searches and orders.*
6. *The GVS PHA acquires PPS, M&PG and Ancillary data products from the A&D and conducts various analyses on the data. The PHA generates the National Map, uses the M&PG atmospheric state data to generate products, and compares these products to PPS observations. The National Map and other products are sent to the A&D.*
7. *The A&D distributes PHA data products to Precipitation Measuring Mission Science Team members and to the general user community according to previously established standing orders or in response to searches and orders.*
8. *The Precipitation Measuring Mission Science Team reviews and analyzes data received from the GVS A&D. Over time, the PMM Science Team proposes new GVS instrumentation and algorithms, which are tested and integrated into the GVS.*

Ground Validation Implementation Concept

Ground Validation Implementation Objectives

- ***GPM scientific objectives include improvement in predicting terrestrial weather, climate and hydrometeorology***
  - *A better observational understanding of the global water cycle is key to meeting GPM mission objectives*

- ***The GPM-GVS has the following subsidiary objectives:***
  - *Evaluation & Diagnosis: Use ground-based measurements (including field campaigns) to improve understanding of precipitation processes for GPM retrieval algorithm and data product improvements*
  - *Improvement: Provide ancillary measurements to improve GPM data applications in climate modeling and numerical weather prediction*
  - *Improvement: Provide testbeds for improving GPM data usage in hydrometeorological modeling and prediction*

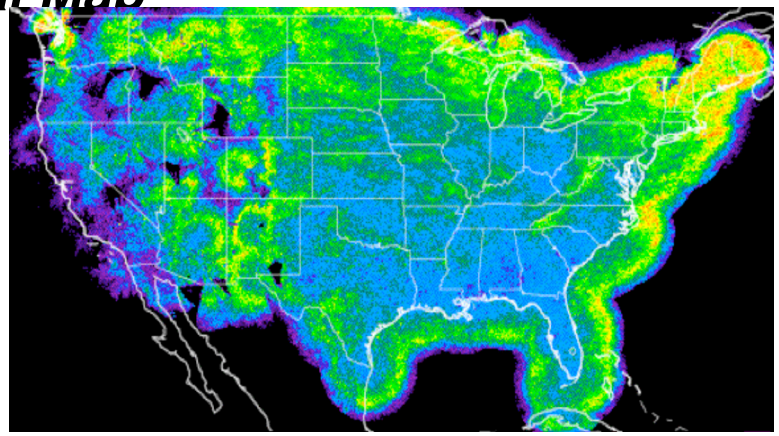
GV Implementation Definition Process

- ***Two GV workshops held with the GPM science community***
  - *June 8-9, 2005: focus on GVS functional architecture, GPM GV products, GV site location and radar trade space and selection criteria*
  - *August 9-10: "GPM Advisory Panel on Ground Measurements"*
    - *Workshop co-hosted with the GPM Science Office*
    - *Provided direction on: location of GPM ground validation sites, scientific objectives for these sites, and recommendations on measurement methods*

- ***GPM Project Scientist GV concept paper***
  - *Re-focused GPM GV objectives so that they address climate modeling, numerical weather prediction and hydrometeorology*
  - *Reference concept shifted from focus on "supersites" to a strategy based on*
    - *Analysis of surface precipitation for statistical validation*
    - *Precipitation process sites and integrated hydrological sites for physical validation*

Statistical Validation

- ***Statistical validation is based on direct comparison of satellite data products with ground instrumentation***
  - *Quantify the bias and errors contributed by ground and space-based instruments*
  - *Contribute to an error model of precipitation measurements*
- ***Statistical validation supports GPM-GV evaluation and diagnosis objectives by***
  - *Building, over time, a statistically significant sample for instrument characterization and product validation*
- ***Implementation Concept: the National Map***
  - *Use US national network of NEXRAD radars and rain gauges to assess first order errors in GPM precipitation retrievals*
  - *Target areas for detailed study in locations where GPM algorithms fail*
  - *Approach is scalable to include non-US locations and observing networks*



Physical Validation

- ***Physical validation is based on hydrologic and atmospheric models run with ground observation data, with the goal to***
  - *Calculate TOA microwave radiative quantities (Z and Tb) observed by the GPM Core Satellite (or other targeted satellites) to within sensor noise*
  - *Calculate precipitation quantities that are identical to those generated by the GPM standard algorithms*
  - *Close water and energy budgets*

- ***Physical validation thus supports the GPM-GVS improvement objectives by:***
  - *Providing a testbed where physical assumptions of the GPM precipitation algorithms can be evaluated, revised and refined*

- ***Implementation Concept: Targeted observations at hydrological and precipitation process sites***
  - *Characterize the microphysical properties of clouds in different precipitation regimes and relate them to cloud processes and satellite observables*
  - *Relate satellite-based rainfall estimates to hydrological measurements*

Instrumentation and GV Site Locations

- ***Specific GV instrumentation and site locations are TBD in lower-level documentation…***

  …but here is the current system concept

- ***Two sets of GV instruments, with an emphasis on mobility***
  - *Nominally, each set has a truck-mounted X-band dual polarization radar and S-band radar profiler, with deployable disdrometers and rain gauges*
  - *Aircraft microphysical and radiometric measurements are also part of the concept*

- ***The national map is used to target instrument observations***
  - *Adaptive decisions on ground and aircraft deployments are made throughout the GPM mission*
  - *Ground deployments may be as short as a season or as long as several years, depending on issues to be addressed*

Concept Compared to GPM GV Objectives

- ***Evaluation and Diagnosis***
  - *The National Map provides a measure of measurement bias and uncertainty*
  - *The National Map identifies where the GPM precipitation retrievals work and where they fail*

- ***Improvement***
  - *GV measurements targeted by the National Map test physical assumptions of the GPM precipitation algorithms in areas with known problems*
    - *GV measurements provide the means for revising algorithm parameterizations or other assumptions*
  - *GV measurements integrated with hydrologic test sites provide objective measure of error and bias of satellite-based precipitation estimates*
    - *GV measurements provide a bridge between satellite observations and assimilation of those measurements in numerical weather and hydrologic prediction models*

Wrap-Up

Risks

- ***No significant risk items for this phase of development***
- ***9 GVS risk items identified during various project-internal and peer reviews***
  - *8 of these risks are to be worked off by PDR*
  - *1 of these risks is to be worked off by CDR*
  - *All of these risk items are considered "moderate" to "low"*
- ***See backup charts for details of GVS risk items***

GVS Risk Items 1 of 2

GVS SEGMENT RISK ITEMS

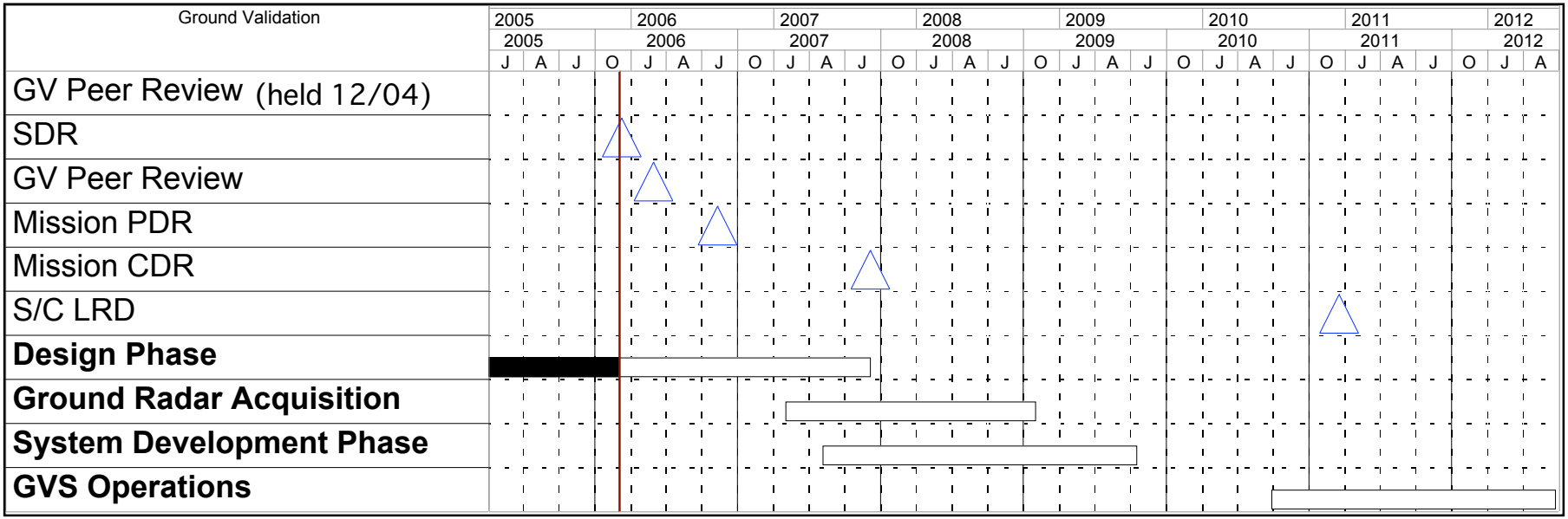
Risk Item Title	ID Number	If...	...then	mitigation	Notes	RMP prob	RMP impact	overall risk	resolution date
Forward modeling parameterization. Ground instrumentation may not be able to accurately measure key parameters in the forward model(e.g., cloud liquid water in precipitating clouds)	GVS-1	If ground measurements cannot successfully parameterize the forward model...	...then it won't be possible to simulate TOA Tbs and Zs	Feasibility & trade studies directed toward assessment of model sensitivity and to development of ground instrumentation experimental design. To be resolved by PDR.	Risk origin = L2 requirements delta peer reivew RID#3 (Hou), RID#4 (Huffman), RID#6 (Meneghini), RID#12 (Olson)	C	D		PDR
Ground instrumentation cost. Although the GPM-GVS budget is set, a detailed assessment of implementation costs has not yet been made	GVS-2	If the cost of implementing the design presented in this review exceeds the available budget...	...then some key capabilities may not be implemented	Feasibility & trade studies include cost assessment of ground site(s) location, validation equipment, implementation & ops. Strategies for phasing capabilities will also be part of the studies. To be resolved by PDR.	Risk origin = L2 requirements delta peer reivew RID#8 and RID#9 (Meneghini), RID#13 (Olson)	C	C		PDR
Validation of GVS SSM. Validation of the GVS SSM may require aircraft data collection	GVS-3	if funds are not available for at least 1 aircraft campaign to validate the MOV to SSM to TOA Tb and Z...	...then complete validation of the SSM error/uncertainty characteristics may not be possible	Review budget at PDR to determine whether GPM GVS funds are sufficient to conduct at least one aircraft data collection/validation campaign over the MOV/SSM. Funds for aircraft campaigns may also be available via NASA HQ NRA.	Risk origin = L2 requirements delta peer reivew RID#22 (Starr). 6/05 funds for aircraft validation now included in POP-05; verify that budget is adequate at PDR and then close this item	A	B		PDR
Generation, delivery, I&T of GVS sicence code.	GVS-4	if PMM Science Team delivery of code for the MOV/SSM is delayed	...then the GVS functionality will be delayed and/or costs will escalate	Include plans for handling the development, of GVS science code (including peer review), delivery, integration and test of science code in a GVS Management Plan. Management Plan should be delivered by PDR.	Risk origin = L2 requirements delta peer reivew RIDs#27 and 29 (Starr). 6/05 implementation plan now calls for pre-CDR prototyping to mitigate this risk	A	D		PDR
GVS supersite rain event algorithm not defined	GVS-5	if the event(s) that triggers the definition of "its raining" is not properly defined...	...then the GVS may over or under sample rain events	Define the size of the supersite(s), including definition of how close to the center volume of the site does a rain event trigger the site to declare "its raining". Defnintion due at CDR.	Risk origin = L2 requirements delta peer reivew RID#25 (Starr).	B	B		CDR
Kawajalein reliability	GVS-6	If the Kwajalein radar remains unreliable in terms of calibration and quality of polarimetric data...	...then the data will not be useful for SSM data products (and the money invested in Kwaj will not get a useful scientific return)	Feasibility & trade studies include a task (#5) to specifically address Kwaj calibration and operations. Go-NoGo decision on Kwaj by PDR.	Risk origin = L2 requirements delta peer reivew RID#10 (Meneghini).	C	D		PDR

GVS Risk Items 2 of 2

GVS SEGMENT RISK ITEMS

Risk Item Title	ID Number	If...	...then	mitigation	Notes	RMP prob	RMP impact	overall risk	resolution date
GVS Product definitions	GVS-7	If the GVS products are defined in terms of retrieved parameters (e.g., water contents) …	…then there may be an incompatibility between the GVS-derived parameters and the forward model that they are to constrain	Feasibility & trade studies include are intended to define the GVS products; need to define Level 1,2,3 products (RID#11); it is recommended that GVS MOV measurements (e.g., radar reflectivity) be provided as a product to the SSM instead of or in addition	Risk origin = L2 requirements delta peer reivew RID#14 (Olson), RID#7 and RID#11 (Meneghini), RID#17 (Privette). 6/05 a draft set of GV products has been developed; workshop scheduled to coordinate model requirements and product list	A	C		PDR
Ancillary data products	GVS-8	If the PMM science team defines requirements for anccillary data products needed for GVS product generation …	…then there may be cost or schedule impacts in meeting the requirements	Feasibility & trade studies include are intended to define the GVS products these studies (to be completed by PDR) will determine whether there are any outstanding requirements for anciallary data products	Risk origin = TBDs in L2 requirements and peer review RID#37 6/05 a draft set of GV products has been developed; workshop scheduled to coordinate model requirements and product list, no ancillary products identified so far	B	C		PDR
Configuration management	GVS-9	If the GVS is not running a near "carbon copy" of the PPS algorithms & processing environment…	…then algorithm improvements recommended by the GVS may not be effectively integrated into the PPS	Need to analyze the procedures that PPS has in place for integrating algorithm improvements into the PPS, and 1) define system requirements on GVS by PDR, 2) define GVS procedures by CDR	Risk origin = L2 requirements delta peer reivew RID#18 (Privette) and RID#24 (Starr).	C	A		PDR

GPM-GVS High-Level Schedule



See backup charts for notional implementation plan

Road to PDR

- ***Activities in FY05 was focused on feasibility and trade studies***

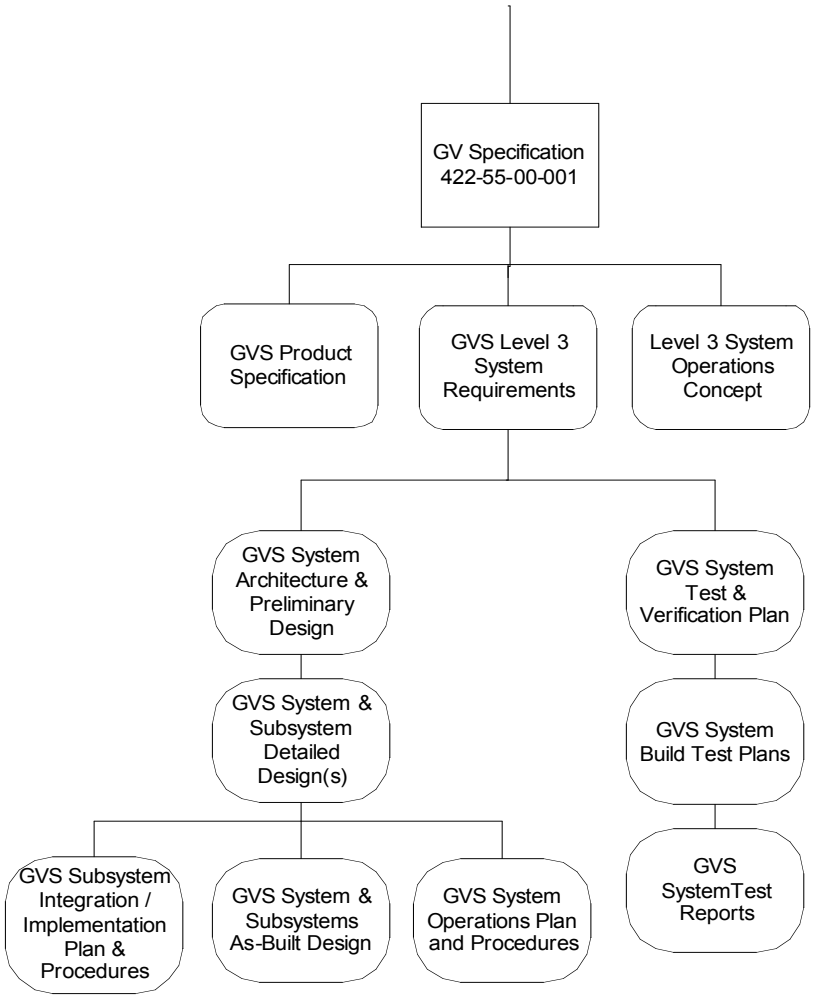
  Support solicited from the PMM Science Team for 5 studies

  – *Satellite Simulation Model (SSM) and Model Sensitivity*
  – *Precipitation Network Design and Operations Planning*
  – *SSM Ground Instrumentation Design and Operations Planning*
  – *Acquisition of Space-Time Coincident Satellite and Ground Measurements*
  – *Kwajalein Radar-Profiler Instrumentation Operations Planning*

- ***Activities in FY06 will focus on PDR and prototypes***

  – *Ramp up team in systems engineering and programming support*
  – *Focus on documentation development (requirements and ops concept) for PDR, and the statistical validation prototype*

Document Tree



Document	Draft	Final
GVS Level 2 Requirements Specification		SDR
GVS Level 3 Requirements	SDR	PDR
GVS System Architecture and Preliminary Design	SDR	PDR
GVS System and Subsystem Detailed Design	PDR+6 months	CDR
GVS Subsystem Integration/Implementation Plan & Procedures	PPDR+6 months	CDR
GVS Operations Plan and Procedures	Draft at each Build Design Review (BDR)	Revised at each Build Acceptance Review (BAR) Final at ORR
GVS System Test & Verification Plan	Draft at each BDR	Revised at each BAR Final at ORR
GVS System Build Test Plans	Draft at each BDR	Revised at each BAR Final at ORR
GVS System Test Reports		Final at each BAR
GVS System & Subsystem As-Built Design	Revised at each BAR	Final at ORR

Back-Up Charts

Acronyms & Abbreviations

A&D	Archive and Distribution
CDR	Critical Design Review
CM	Configuration Management
CMO	Configuration Management Office
DPR	Dual-frequency Precipitation Radar
GCM	Global Climate Model
GMI	Global Microwave Imager
GPG	Goddard Project Guideline
GPM	Global Precipitation Measurement
GSFC	Goddard Space Flight Center
GV	Ground Validation
GVS	Ground Validation System
ICD	Interface Control Document
L1	Level 1 (requirements)
L2	Level 2 (requirements)
MAR	Mission Assurance Requirements
MPG	Measurement and Product Generation Function
MBA	Model-Based Analysis
MCR	Mission Confirmation Review
MD	Metrics Database
MOC	Mission Operations Center
MOV	Multidimensional Observing Volume
MW	Microwave

NASA	National Aeronautics and Space Administration
NPG	NASA Program Guideline
NWP	Numerical Weather Prediction
ORR	Operational Readiness Review
PDR	Preliminary Design Review
PMM	Precipitation Measuring Mission
PPS	Precipitation Processing System
PR	Precipitation Radar (TRMM instrument)
Q/A	Quality Assurance
RFA	Request for Action
RID	Request for Information or Determination
RT	Radiative Transfer
RTE	Radiative Transfer Equation
SSM	Satellite Simulator Model
Tb	Brightness Temperature
TOA	Top-Of-Atmosphere
TBD	To Be Determined
TRMM	Tropical Rainfall Measuring Mission
Z	Reflectivity

TRMM GV Lessons Learned—1 of 2

- ***The TRMM GV lessons learned were compiled by Dave Wolff in a December 11, 2003 presentation***

Lessons learned applicable to this phase of design

TRMM Lesson Learned	GPM Remedy
GV requirements must be science (i.e. Science Team) driven, including specification of instrumentation, and how and when they are calibrated	GVS has data and operational interfaces to the PMM Science Team (Ops Con & Requirements)
A GV Science Team that interacts with the GV Operations group and satellite algorithm developers should be a high priority	PMM Science Team is being funded to assist in GVS formulation and development (Implementation Planning)
Development of processing algorithms should be a science responsibility, and scientists must be involved in QC development and validation	
Are the specified science products actually useful to the science team and algorithm developers? There should be agreement by the GV and satellite communities prior to implementation.	GV concept includes algorithm developer-provided model-based validation elements. Implementation planning (chart #50) includes funding for science team contributions to GVS detailed design
Thorough and consistent radar and gauge calibration is a must!	added to GVS L3 requirements
simply processing data and generating products is not sufficient; we must evaluate the products and describe their systematic errors and uncertainties	added to GVS L3 requirements
Better to do a few sites well than several sites poorly!	notional implementation is with 2 sites only
GPM should have a fully tested and fully functional data processing system complete with QC testing procedures demonstrated at least six months prior to launch of core satellite	GVS requirement to be ready 6 months prior to launch

TRMM GV Lessons Learned—2 of 2

Lessons learned applicable to the detailed design phase

TRMM Lesson Learned	GPM Remedy
A dense rain gauge network, which can characterize the spatial variability of precipitation and provide sufficient gauge sampling to effectively match a radar pixel is highly desirable if not required	To be defined by PDR/CDR
Co- or triple-location of rain gauges, and redundancy in gauge loggers strongly encouraged	To be defined by PDR/CDR
Selection criteria of sites must consider the location of the sites and the representativeness of the satellite measurements over that area	To be defined by PDR
De-centralized processing of data did not work well	Location of processing elements to be defined by PDR

Notional Schedule/Implementation Plan—1

- ***Prototype-1 (Begin 8/05 End 9/06)***
  - ***Science coding (e.g., in IDL) of the forward radiative transfer model and radar simulator***
  - ***Use of archive data or simulated data for input into the science code***
  - ***Validation of the forward modeling by comparison of Prototype–1 results with satellite passive microwave and radar data***
- ***Prototype-2 (Begin 8/06 End 9/07)***
  - ***Science coding (e.g., in IDL) of the forward and constrained inverse radiative transfer model***
  - ***Use of archive, near-real time, and (minimally) simulated data for input into the science code***
  - ***Validation of the forward modeling by comparison of Prototype–2 results with satellite passive microwave and radar data***
  - ***Preliminary rain gauge and disdrometer network fielded in the US (<10% of final capability)***
  - ***Comparison of constrained inverse modeling to rain rate products from GVS rain gauge network***
- ***Build-1 (Begin 5/07 End 6/08)***
  - ***Key modeling algorithms ported to the development and pre-operational computing environments, modeling product format and content verified***
  - ***Gauge and disdrometer networks fielded at US and oceanic sites (about 40% and 20% complete, respectively); instantaneous rainfall products available from the networks, product format and content verified***
  - ***Prototype ingest of profiler and radar data***
  - ***Limited performance interface and data exchange with PPS***
  - ***Limited performance storage and retrieval of PPS, modeling, and ground-site products verified***

Notional Schedule/Implementation Plan—2

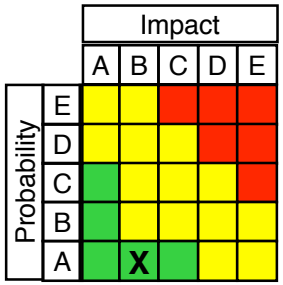
- ***Build-2 (Begin 5/08 End 6/09)***
  - *Profiler instrumentation fielded and field tested*
  - *Version-1 SSM product generation coding is complete and verified.*
  - *Version-1 user interface is complete and verified*
  - *External interfaces (with PPS and others) are complete and stress tested*
  - *Product generation and storage/retrieval capabilities are verified at full performance levels*

- ***Build-3 (Begin 5/09 End 6/10)***
  - *All product generation coding is complete and verified*
  - *User interface is complete and verified*
  - *Ground radar fielded and tested; routine radar and other ground-product generation*
  - *Requirements for security compliance verified*
  - *All systems fully ported to operational environment with verified performance*
  - *Validation of ground/model/satellite inter-comparison by science users*

H-25: RFI Between Supersite and Spacecraft

Risk Statement: Given that there will be active radars on the spacecraft and on the ground and that they may "illuminate" each other during an overflight; the radio frequency interference between these two instruments could render data useless and/or cause damage to the radars and/or radiometers.

Risk Data:
Level: Element (GVS)



Owner: Matt Schwaller
Timeframe: Short-Term

Mitigation: Conduct a link budget analysis to determine effect to radars. Conduct a study to determine the effect on the data.

6/10/05—Coordinate closely with GVS to ensure that the GV radar(s) to be built won't interfere by designing them at a frequency at least 10MHz away from the DPR's Ku and Ka frequencies.

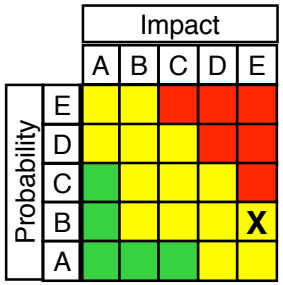
Contingency: The GV radar transmission shall be defeated for a few seconds about the precise moment of satellite footprint overpass (pending testing of Core instruments for sensitivity to GV radar frequencies).

H-26: Control at GV Supersites

Risk Statement: Given that the NASA provided GV Supersites may rely upon resources that are not in NASA's control; NASA may lack direct authority of its assets, possibly impacting GPM's mission objectives.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

Mitigation: Determine what Standard Operating Procedures (SOP) are currently in place and how they impact NASA assets. GPM and NASA HQ should develop MOUs that will ensure GPM's mission objectives are not compromised by sharing sites.

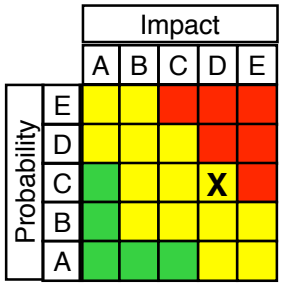
Contingency: If SOP's or other documentation indicates that sharing the sites may compromise GPM's objectives and the sharing entities do not agree to the terms in an MOU, GV sites should be sought that do not require sharing or that are more in line with GPM's mission objectives.

H-27: GVS Forward Modeling Parameterization

Risk Statement: Given that the ground instrumentation may not be able to accurately measure key parameters in the forward model (e.g., cloud liquid water in precipitating clouds) and may not be able to parameterize it; it may not be possible to simulate TOA Tbs and Zs.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

Mitigation: Conduct feasibility and trade studies directed toward measurement of model sensitivity and development of ground instrumentation experimental design.

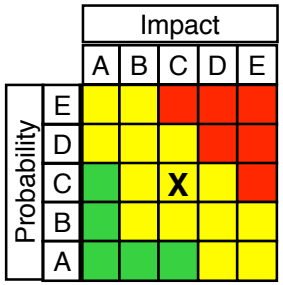
Contingency:

H-28: GVS Ground Instrumentation Cost

Risk Statement: Given that the GPM-GVS budget has already been determined and a detailed assessment of implementation costs has not been made; there is potential that implementing the desired design may exceed the budget and some key capabilities may not be implemented.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

Mitigation: Conduct feasibility and trade studies which will include cost assessments of the GV ground site(s), validation equipment, implementation, and operations. Strategies for phasing capabilities will also be part of the studies.

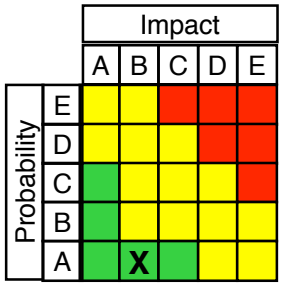
Contingency:

H-29: Validation of GVS SSM

Risk Statement: Given that GPM is under tight budget constraints; there may not be funds available for at least one aircraft campaign to validate the MOV to SSM to TOA Tb and Z and complete validation of the SSM error/uncertainty characteristics may not be possible.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

Mitigation: Review budget at PDR to determine whether GPM GVS funds are sufficient to conduct at least one aircraft data collection/validation campaign over the MOV/SSM. Funds for aircraft campaigns may also be available via NASA HQ NRA.

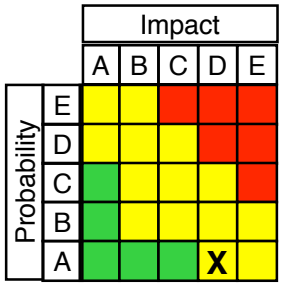
Contingency:

H-30: GVS Science Code

Risk Statement: Given that the PMM Science team is responsible for development and delivery of code for the MOV/SSM and code development often is delayed; the GVS functionality may be delayed and/or costs may escalate.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

Mitigation: Include plans for handling the development (including peer reviews), delivery, integration and test of the GVS science code in a GVS Management Plan. The Management Plan will be delivered by PDR.

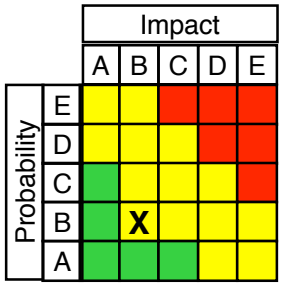
Contingency:

H-31: Supersite Algorithm Undefined

Risk Statement: Given that the event(s) that trigger the definition of "it is raining" have not been sufficiently defined; it is possible that the GVS may over sample or under sample rain events.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Long-Term

Mitigation: Define the size of the Supersite(s), including definition of how close to the center volume of the site that a rain event triggers the site to declare that "it is raining". Definition due at CDR.

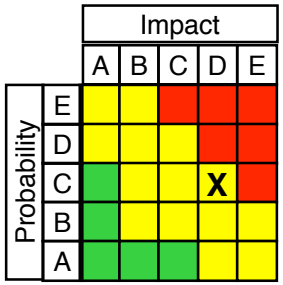
Contingency:

H-32: Kwajalein Radar Reliability

Risk Statement: Given that the Kwajalein radar is still unreliable regarding the calibration and quality of polarimetric data; it is possible that the data will not be useful for SSM data products and the money invested in Kwaj will not produce a useful scientific return.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

Mitigation: Task #5 of the feasibility and trade studies specifically addresses Kwaj calibration and operations.

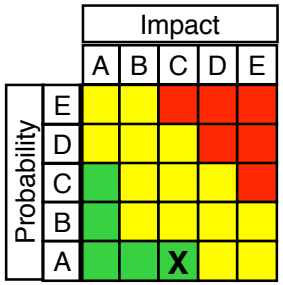
Contingency:

H-33: GVS Product Definition

Risk Statement: Given that the GVS products may not be defined in terms of retrieved parameters (e.g., water contents); there may be an incompatibility between the GVS-derived parameters and the forward model that they are to constrain.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

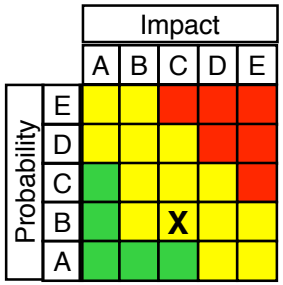
Mitigation: Feasibility and trade studies will include defining the GVS products; Levels 1, 2, and 3 (RID #11). Ensure that the GVS MOV measurements (e.g., radar reflectivity) be provided as a product to the SSM instead of, or in addition to, ground-radar derived rainfall estimates. Also must define product geometry (RID #7) and a long-term trending product for vicarious calibration (RID #17).

Contingency:

H-34: Ancillary GV Data Products

Risk Statement: Given that the PMM Science team may define the requirements for the ancillary data products needed for GVS product generation; it is possible that there will be cost and/or schedule impacts to meet the requirements.

Risk Data:
Level: Element (GVS)



Owner: Matt Schwaller
Timeframe: Short-Term

Mitigation: Feasibility and trade studies (to be completed by PDR) will include defining the GVS products. These studies will determine if there are any outstanding requirements for ancillary data products.

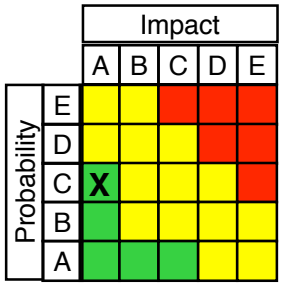
Contingency:

H-35: GV Configuration Management

Risk Statement: Given that GVS will not be running a near "carbon copy" of the PPS algorithms and processing environment; it is possible that the algorithm improvements recommended by the GVS will not be effectively integrated into the PPS.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Long-Term

Mitigation: Analyze the procedures that the PPS has in place for integrating algorithm improvements. Define system requirements for GVS by PDR and GVS procedures by CDR.

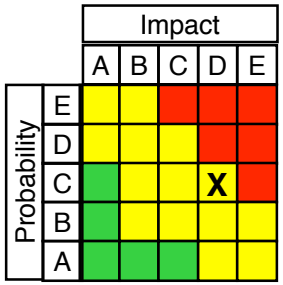
Contingency:

H-36: GVS Requirements for GMI/DPR Calibration Undefined

Risk Statement: Given that GVS will participate in the Core GMI/DPR calibration activities during commissioning and the requirements for the activity remain undefined; the GVS schedule may slip and/or costs escalate as GVS planning continues without all of the necessary requirements defined.

Risk Data:

Level: Element (GVS)



Owner: Matt Schwaller

Timeframe: Short-Term

Mitigation: GPM Systems Engineering and Project Scientist will review/define GVS requirements for GVS participation in GMI/DPR calibration activities during commissioning phase prior to the delta Systems Requirements Review.

Contingency:

Agenda

Day 2 - December 7, 2005
Location: NASA GSFC B16W-N76/80

Time	Section	Event	Presenter
8:30 AM	12	Core Spacecraft Management	Horowitz
9:30 AM	13	Primary Spacecraft Systems Engineering	O'Neill
11:00 AM		**Break**	
11:15 AM	14	Mission Operations System Concept/Requirements	Rykowski
12:15 PM		**Lunch**	
1:15 PM	15	Precipitation Processing System Concept/Requirements	Stocker
2:15 PM	16	Ground Validation	Schwaller
3:15 PM		**Break**	
3:30 PM	17	Risk Assessment	Durning
3:45 PM	18	Review Wrap Up	Durning/Ho
4:00 PM		Review Team Caucus	
4:15 PM		**End of Day 2**	